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ABSTRACT

This paper responds to calls for further research on learning effectiveness of instructional technologies by comparing 'learning' and 'attitudes' across three instructional environments (multimedia, textbook and in-class instruction), and proposing a quasi-experimental research design approach. The paper reports the results of pilot studies conducted with the aim of refining the research framework, assessing the experimental conditions, and obtaining preliminary results. This research framework and the pilot studies are described. The subjects of the study were graduate and undergraduate students enrolled in business administration degree programs at a major East-coast University. Six figures include: quasi-experimental model for testing the comparative effectiveness of instructional technologies; prior work experience; age of the learners; satisfaction survey data, undergraduate pilot study, fall 1999; prior knowledge of the topic: self-reported prior knowledge and pre-test-posttest differences; appeal response, undergraduate pilot study, fall 1999. (Contains 30 references.) (Author/AEF)

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THE LEARNING EFFECTIVENESS OF INSTRUCTIONAL TECHNOLOGIES: RESULTS FROM PILOT STUDIES

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ABSTRACT

This paper responds to calls for further research on learning effectiveness of instructional technologies by comparing 'learning' and 'attitudes' across three instructional environments (multimedia, textbook and in-class instruction), and proposing a quasi-experimental research design approach. The paper reports the results of pilot studies conducted with the aim of refining the research framework, assessing the experimental conditions, and obtaining preliminary results. This research framework and the pilot studies are described.

INTRODUCTION

Since technology is so widespread in society, different stakeholders believe that educational strategies should reflect this expanding phenomenon by introducing instructional technology in the classroom. They often assume that the effectiveness of technology has been proven once and for all (Roblyer et al, 1997). Instead, the learning effectiveness of instructional technology is yet to be proven. In spite of the several studies (Nugent, 1982; Mayer & Anderson,1991) and meta-analyses (Kulik, Kulik & Shwalb, 1986; Roblyer, Castine & King, 1988; Kulik, 1994; Khalili & Shashaani, 1994;) competing to answer the question: "do computers and other related technologies make a difference in learning? the question on the comparative perfomance of instructional technology is not yet answered. Several scholars are calling for further research (Liao, 1998; Jones & Paolucci, 1998; Fletcher-Flinn & Gravatt, 1995).

The authors try to answer the call for further research with a quasi-experimental design which compares 'learning' and 'attitudes' (satisfaction and appeal) in subjects gaining knowledge of project management topics by either attending a class presentation, reading a textbook, or using an interactive multimedia CD-ROM. The subjects of the study are graduate and undergraduate students enrolled in business administration degree programs at a major East-coast University. The study is replicated, under comparable conditions, with the two groups. The purpose of the replication is to explore whether learning effectiveness and satisfaction vary by age (graduate and undergraduate), and by subject topic characteristics.

Because the results from the implementation of the quasi-experiment are not available at the present time, this paper focuses in describing the theoretical framework, the research design, and the results of the pilot studies that precede the actual testing. The results from the analysis will be available in December 2000.

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THE LEARNING EFFECTIVENESS OF INTERACTIVE MULTIMEDIA SYSTEMS

The authors' expectations based on the literature review is that the instructional conditions that best support multiple representation modes have a higher impact on learning specific content. Instructional technologies such as interactive multimedia allow the integration of multiple media in a specific delivery environment, therefore promoting multiple representations of knowledge. The structural features (organization of content, modes of delivery) of interactive multimedia have an impact in the construction of mental models (Jonassen, 1990) and, particularly, a positive effect on the cognitive system.

Tergan (1997) states that the cognitive processing of multiple external representations (such as the ones in interactive multimedia and hypermedia) matches principles of encoding variability and encoding specificity (Tulving, 1983). The *encoding specificity* principle requires that learning situations contain recognizable clues that help learners understand, locate, and recall information; and that realistic contexts (like the ones in interactive multimedia systems) generally result in better performance. The principle of *encoding variability* is also supported by interactive mltimedia multiple representation modes. The fact that information is encoded in a variety of formats increases the chances that at least one of the representations corresponds to the context of use in a particular situation (Hammond, 1993).

The value of interactive multimedia learning is also supported by the principles of cognitive flexibility theory (Jacobson & Spiro, 1995); multimodal cognitive processing (Cunninhgham et al., 1993); and individualized and self-regulated instruction (Duffy & Knuth, 1990). According to the *cognitive flexibility theory*, interactive multimedia environments employ multiple ways to represent knowledge in instructional activities, thus reflecting the nature of complex knowledge. This contributes to the development of cognitive structures that are flexible enough to be applicable to different contexts, enhancing knowledge transfer. Paivio (1986) finds that using visuals and other representational modes entails *dual coding*, which enables humans to better retain information. Paivio's theory is supported by recent developments of multimedia approaches to learning (Engelkamp & Zimmer, 1994). Remembering, for example, may be enhanced because information is represented in different cognitive systems.

The learning effectiveness argument for multimedia is also supported by the *multiple intelligences theory* (Gardner, 1984, 1993) and *emotional intelligence theory* (Goleman, 1995). Multiple symbolic modes promote synergistic interactions among several intelligences (spatial, kinesthetic, logical-mathematical, musical, linguistic, interpersonal, intrapersonal) and benefit learning in the various domains - cognitive, affective, psychomotor - (Kemp, 1994). Computer-based media support the social dimensions of human learning, interpersonal and intrapersonal intelligences, to an astonishing degree (McLellan, 1996).

By affecting different domains (cognitive, affective and psychomotor) multimedia also allows mass-customization of instruction, since instruction offered in several modes is adaptable to the individual learner. Different learners are more attuned to different types of representations (Keller, 1983) and implementing reinforcing activities may enable them to "explicitly or "implicitly select the activity that is most "customized to their cognitive skills (McLellan, 1996). In addition, by shifting between different representations, learners get multiple practice (Marks-Tarlow, 1995).

RESEARCH DESIGN

In this framework, the main question of the researchers is *'Whether interactive multimedia applications are effective learning tools compared to traditional learning environments (textbook, or in-class instruction).'* To test the learning effectiveness of interactive multimedia, this study adopts the definition of learning in Merrill's performance-content matrix model (1983). Based on this definition, the *independent variables'* (the three instructional settings, such as the class presentation, the textbook, and the multimedia CD-ROM) effects on the learning of project management topics (*dependent variable*) are examined through comparing subjects' recall and application performance in specific content areas (recall and application of facts, concepts, principles, and procedures). Subjects' attitudes (*dependent variable*) across the instructional settings are investigated through learners' comparative satisfaction with the instructional materials (see *Figure 1*).

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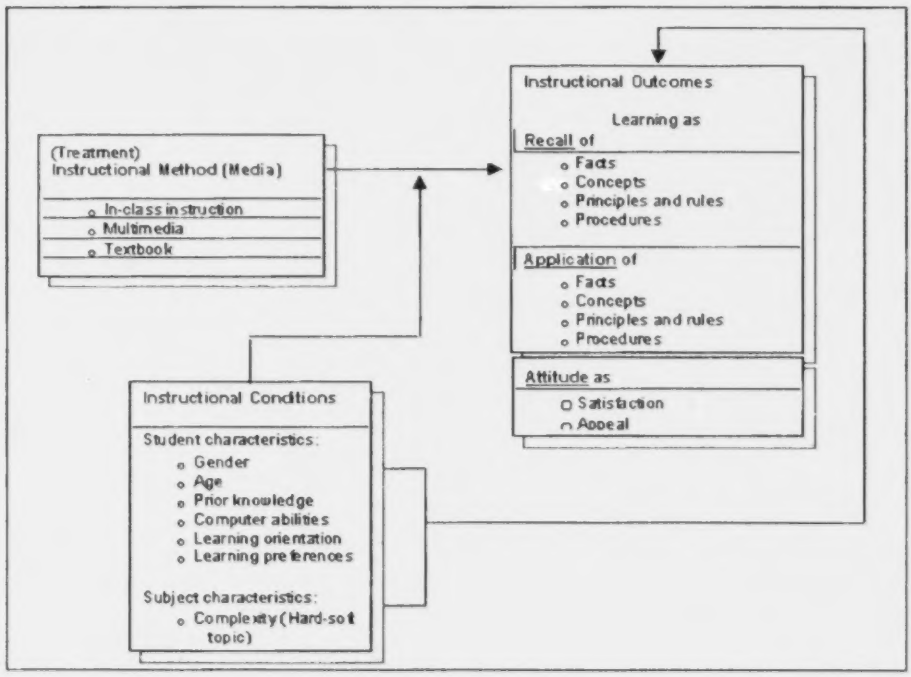
FIGURE 1
QUASI-EXPERIMENTAL MODEL FOR TESTING THE COMPARATIVE EFFECTIVENESS OF INSTRUCTIONAL TECHNOLOGIES



The *intervening variables* include: *student characteristics* such as gender, age, prior knowledge, computer abilities, and learning preferences; and, *subject characteristics*, such as complexity of the topic (high and low complexity). Assessing learners' prior knowledge of the topic and reporting their demographic breakdown reinforces the research design. It enables comparing and contrasting the treatment and control groups, as well as developing a better understanding of the characteristics of the students surveyed.

Because the effectiveness of the instructional materials may also depend on learners' prior experience in management, the study utilizes a pre-test & posttest design to assess learners prior knowledge of the topic. In addition, the demographic survey collects data on learners prior work experience (see, for example, *Figure 2*), major, and computer utilization.

Related questions associated to the model presented in Figure 1 and based on Merrill's (1983) performance-content matrix include:

Which environment is more effective at achieving learning objectives (recall or application)?

Which environment is more effective at delivering a specific type of topic (with high/low complexity)?

Which environment, if any, is more appealing for the learners' groups (graduate, undergraduate) targeted?

The responses to these questions based on the implementation of the study will be available in December 2000. Although it is expected that it will be difficult to make clear-cut and distinct statements on the instructional effectiveness of technology (interactive multimedia may be more effective for specific content areas, such as recall of facts and principles, but less effective in applications of procedures), the authors set up a study that tries to overcome the limitations recognized in earlier studies.

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DIFFICULTIES AND REMEDIES

There are many factors that can influence the results of effectiveness studies. The researchers recognize the difficulty and address the objections brought to similar comparative learning research. In particular, Clark (1983) offered many objections to the value of the analyses that claimed comparatively positive outcomes in educational technologies. According to Clark (1983) the most common sources of confounding evidence in earlier studies appeared to be the uncontrolled effects of: *a)* instructional method or content differences between treatments that are compared; and *b)* novelty effect for newer media, which tends to disappear over time.

1. The research design of this study addresses Clark's considerations and tries to isolate learning from the medium by limiting the instructional time, controlling the learning environment, and assessing the role of intervening variables.

2. To address Clark's first concern (point *a*), the researchers focus on *one* specific technology (multimedia) and compare its effectiveness with both classroom and text-based instruction in teaching project management modules using the *same* teaching materials. The characteristics of the instructional material are briefly described to provide support to the comparability statement.

   The Textbooks

   The textbooks from which the multimedia CD-ROM, and the in-class instruction, are based are two major project management publications.

   > Frame (1994) The New Project Management: Tools for an Age of Rapid Change, Corporate Reengineering, and Other Business Realities. The Jossey-Bass Management Series
   >
   > Frame (1995) Managing Projects in Organizations: How to Make the Best Use of Time, Techniques, and People. The Jossey-Bass Management Series

   Both publications are ranked highly (number of sales, and reviewers' comments) in the project management literature. They both present similar design and layout features, and they both address complementary topics. They use diagrams and drawings to reinforce understanding, offer several examples, and occasionally include mini-case studies to foster reflection and application. The case studies present problems, and solutions, to emulate a mechanism of feedback provision.

   The multimedia CD-ROM

   The 'Project Management in Organizations (PMO) CD-ROM' is the multimedia version of Frame, 1994 & Frame, 1995. The CD-ROM closely follows the books' organization: learning units mirror chapter titles and structure. The application is designed to teach the fundamentals of project management. Audiences vary from aspiring project managers, project team members, executives, or other stakeholders interested in learning project management.

   The CD-ROM provides a stand-alone tool for learning project management introductory topics and is copyrighted by the Education Services Institute - ESI-International, 1997. It includes different media formats and features:

   > full motion video
   > audio files
   > text-based animation
   > extensive interactivity (with case studies and other exercises)
   > high-quality graphics
   > user-friendly navigation interface

   It also offers a Toolbox with examples of tools, access to Resources (calculator, glossary, notepad), and an Organizer, to sort information in the program, and access testing.

   In-class instruction

   The lecture presentations by J. Davidson Frame are supported by the use of overhead transparencies. The transparencies follow the organization of Frame, 1994, 1995. They display the graphical images of the textbook, and develop additional graphical representations. The instructor primarily uses markers to write on transparencies during the presentation. Occasionally, display boards are used to support explanations.

The instructor offers several examples, asks frequent questions to the audience, provides feedback to responses, and encourages participation through in-class discussion of section problems. Frequently, cases and other exercises are completed in-class, with the instructor support.

3. The study does not address the issue of "novelty. Clark's point *b)* suggests that the use of technology has an initial positive impact on learning, but this impact is lowered over time (what Clark calls "*novelty* effect). Clark himself (Clark & Sugrue, 1995) reports that some studies on the use of computers in college (Kulik & Kulik, 1980) did not find any evidence for the novelty effect. Kulik and Kulik's comparisons of studies of one or two hours duration, vs. studies which held weekly sessions for an entire semester, reported that the effect sizes on learning were roughly the same. Clark responds to these findings by pointing to the fact that the use of computers may be a less "novel experience for college students than for other younger students (p.354).

Because the subjects of this research are college students, following Kuliks' findings and Clark's own considerations, this study limits the length of the instructional modules to short-segments of instruction (from 1 hour and 15 minutes to 2 hours of instruction). Moreover, the limited length of the instructional modules enables focusing on the impact of the medium on achievement and satisfaction rate by eliminating competing variables (such as "total study time) that studies with delayed post-testing may introduce. The researchers recognize that the use of short-instructional modules introduces some limitations regarding the types of knowledge and performance tasks that are achievable within the limited timeframe.

METHODOLOGY AND FOCUS REFINEMENT THROUGH PILOT STUDIES

Three pilot studies precede the refinement of both the theoretical framework and the procedures described in this study. They are valuable elements of the quasi-experimental approach and are, therefore, reported in this paper.

Research Methodology Refinement – Pilot Study (1)

A first pilot study has been instrumental to refine the methodological approach (and deciding between a short-term approach vs. a longer-term study). The researchers' aim to exploit the advantages of the media by offering participants the opportunity to use the textbook/s, or the CD-ROM at their own timing, outside of a laboratory environment, and with little control of the instructional conditions has been prevented by a high-mortality rate.

The sample population for this first pilot designed to assess the feasibility of a long-term self-paced study was composed of working professionals registered to monthly workshops in Project Management offered by a major project management educational services institution in the US. Individuals registered to the workshop received an invitation to participate in the study. Volunteers were randomly assigned to two treatments (interactive multimedia CD-ROM or textbook-instruction). Individuals registered in the workshop were assigned to the lecture treatment. They completed paper-and-pencil surveys. Volunteers in the other treatment groups took all the surveys on-line.

The outcomes of this pilot study supported the need of controlling for instructional conditions, thus undertaking the study in a real-laboratory setting. Although interactive multimedia applications are designed to support self-paced instruction, learners need to receive constant reinforcement and feedback to complete the training program. Although over 23% of the 100-individuals contacted volunteered their participation, 13% dropped prior to receiving the instructional materials. Of the remaining 10% who received the instructional materials, only 5 people completed the study on time (prior to their scheduled training session). The high mortality rate has been instrumental in redesigning the research to test, only in a controlled setting, graduate and undergraduate groups enrolled in business administration degree programs.

Demographic Sample – Pilot Study (2)

Another pilot study was conducted with the objective of testing scale reliability and assesses the comparability of MBA-Cohort groups. The pilot was held during the laboratory sessions of two sections of an MBA-Cohort Information System course. Students enrolled in

Tuesday and Wednesday's laboratory sessions (hereafter referred to as Tuesday, or Wednesday students) took an on-line questionnaire on project management topics ranging from Time Management, Cost Management, Human Resources Management, Risk Management, Communication Management, and Scope Management. They also completed a demographic survey.

The purpose of the demographic survey was to compare the characteristics of the Tuesday and Wednesday groups to identify any specific group composition bias, which could inhibit the generalizability of the findings, and caution against the use of the scale in the actual study. The demographic data evaluated group variances. The frequency results of the demographic surveys confirmed that difference between the two groups (Tuesday and Wednesday) in this population are minimal:

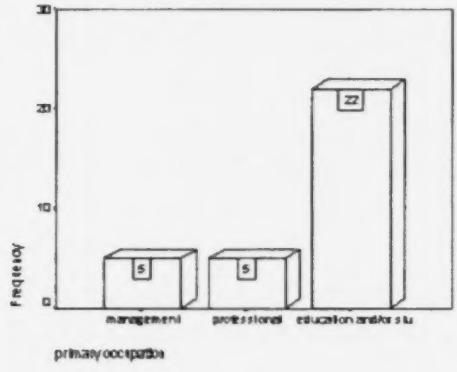
65.5% of the Tuesday participants are Asians/Pacific Islanders, 64.5% of the students in the Wednesday group report belonging to the same ethnicity group. 18.8% (T) vs. 26.9% (W) are Caucasians/White; 75% (T) vs. 81.5% (W) have a college degree, 21.9% (T) vs. 14.8% (W) have a masters degree; 15.6% (T) vs. 14.8% (W) work in a management field, 68.8% (T) vs. 70.4% (W) are in the education field (mostly as students); - see Figure 2 - Additionally: 96.9% (T) vs. 92.6% (W) are between 20 and 29 years old - See Figure 3 -

FIGURE 2
PRIOR WORK EXPERIENCE

Wednesday Group Demographics

WORK1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	management	5	15.6	15.6	15.6
	professional	5	15.6	15.6	31.3
	education and/or student	22	68.8	68.8	100.0
	Total	32	100.0	100.0	
Total		32	100.0		



Tuesday Group Demographics

WORK1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	management	4	14.8	14.8	14.8
	professional	4	14.8	14.8	29.6
	education and/or student	19	70.4	70.4	100.0
	Total	27	100.0	100.0	
Total		27	100.0		

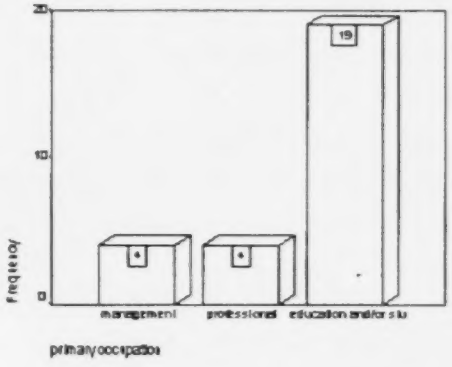


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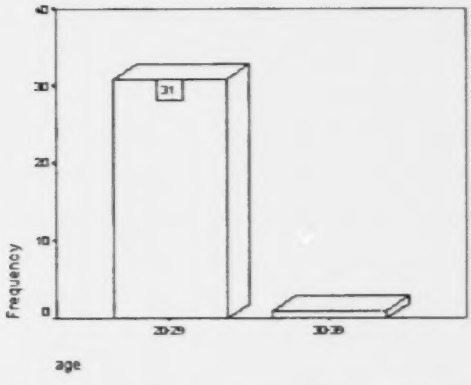
FIGURE 3
AGE OF THE LEARNERS

Wednesday Group Demographics

AGE

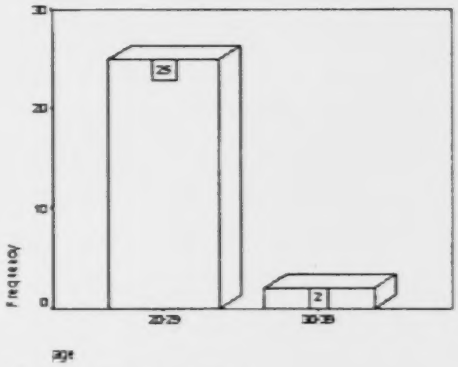
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	20-29	31	96.9	96.9	96.9
	30-39	1	3.1	3.1	100.0
	Total	32	100.0	100.0	
Total		32	100.0		



Tuesday Group Demographics

AGE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	20-29	25	92.6	92.6	92.6
	30-39	2	7.4	7.4	100.0
	Total	27	100.0	100.0	
Total		27	100.0		



43.8% (T) vs. 55.6% (W) report of having been using a computer for 7 years or more;
50% (T) vs. 59.3% (W) are male;
37.5% (T) vs. 40.7% (W) report of having used the computer primarily at work/school, but also at home.

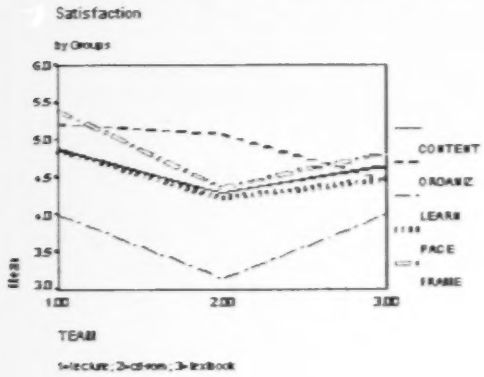
The frequencies values reported above display ranges of differences from 0.9% to less than 10% difference on same measures, with the mode of occurrences concentrating on the lower differences. Because more recent assignments of students to cohort groups have standardized stratification mechanisms, it is expected that similarities in the groups are further increased in the groups participating in the redesigned study.

Satisfaction & Attitudes – Pilot Study (3)

A pilot test of the undergraduate students (senior level) was undertaken in one section of a 'Change in Organizations' course. The main objective of the pilot was to collect feedback on undergraduate students' appreciation of the selected project management topic, and their attitudes toward the experimental procedures (i.e. special attention focuses on their reactions to the presentations, and their interest in attending another session on the topic). Because the sample size of the pilot group was small (44 students present in the sessions), and their subgroups were composed of only 15 or less students, the results from the statistical analysis are not reliable, and are omitted in this discussion. Interesting findings, however, emerge from the descriptive frequencies analysis of satisfaction, and appeal measures (see Figure 5 and Figure 6).

Figure 4 shows that students in the lecture group (#1) were the most satisfied with the organization, pace, content of instruction, and with the instructor's presentation (means > than 4.5). The other groups' satisfaction was also above the mid-point (mean = 4), with the CD-ROM group being more satisfied than the textbook group with the organization of the materials (ORGANIZ). At the same time, the CD-ROM group was the least satisfied in terms of content, pace, and presentation (FRAME). Although the size of each difference was within a 1-point difference, the CD-ROM participants were consistently least satisfied with the materials, and felt that they did not learn the material satisfactorily (LEARN).

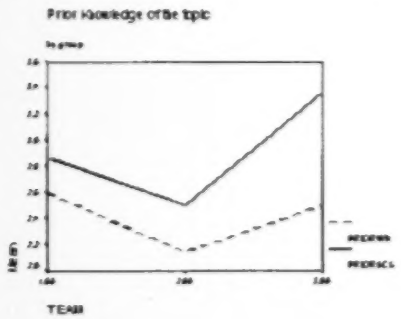
FIGURE 4
SATISFACTION SURVEY DATA, UNDERGRADUATE PILOT STUDY, FALL 1999



It is interesting to compare the values in *Figure4* with other results. Students in the CD-ROM group (#2) reported that they had the least prior knowledge of the topic (Figure 5a), but they obtained the highest pretest and posttest mean scores (Figure 5b), with the limitations that the sample size is not sufficient to use formal parametric procedures, as well as draw conclusions from comparative differences.

FIGURE 5
PRIOR KNOWLEDGE OF THE TOPIC

Figure 5a: Self-reported Prior Knowledge



Additionally, 30% of the students answered that they would like to attend another instructional session similar to the one in which they participated; and 41% answered that they 'may' prefer attending a similar session (Figure 6).

Figure 5b: Pre-TEST—Posttest Differences

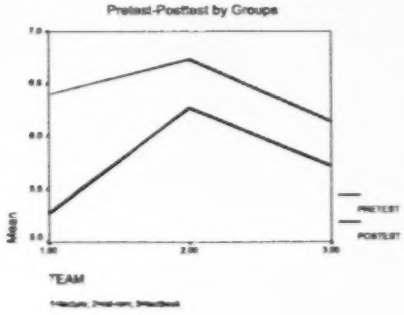
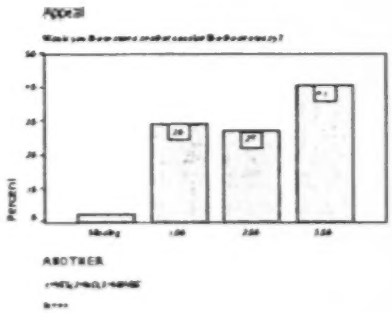


FIGURE 6
APPEAL RESPONSE, UNDERGRADUATE PILOT STUDY, FALL 1999



The appeal measure is encouraging, especially if contrasted with the conditions of the pilot study. Students in this pilot were substantially rushed into the instructional materials because of the logistic arrangements, the lack of proximity of the laboratory and the reading facilities, the need to perform other miscellaneous administrative tasks, substantially reducing instructional time. The CD-ROM group did not complete all the assigned sessions, and spent only a total of 17-minutes using the application. Similar time-constraints characterized the textbook-group; whereas the in-class group is the only group that used the time satisfactorily.

The conclusions of this pilot (#3) led to an improvement in scheduling efforts, with each group meeting directly in the classroom in which the treatment is offered, and reassured the researcher of the appropriateness of using the 'change control' topic with this group of students.

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Lesson learned from this, and the other pilots, guided the implementation of better-enforced laboratory procedures.

CONCLUSIONS FROM THE PILOT STUDIES

The implementation of the pilot studies has been critical to the design of an improved methodology. First of all, it has demonstrated that the ambition to conduct such experiments outside controlled lab environments is tainted with the inability to control the learning process. It results in high-mortality due to conflicting tasks and, above all, lack of reliability of self-reported indication on how/for-how-long the CD-ROM was used. The evaluation of the comparative effectiveness can be conducted only if both the instructional material and the instructional conditions are equivalent (controlled laboratory setting). This calls for the application of these types of experiments only for a limited amount of time, unless the researcher has full control on the many intervening variables (study and practice time, etc.). It is no surprise that similar experiments have led to conclude that there are "no differences in learning across instructional materials . They did not take into account the study-time/efforts of the learners, which obviously influences success in the final exam regardless of the tool used to study the instructional material.

Secondly, the pilot studies have helped assess the comparability of the groups being tested and refined the survey instruments. Thirdly, they have helped screen out learners' attitude (both graduate and undergraduate students) towards the study material, which is also another important component of students' learning.

VALUE OF THE STUDY

Once if is completed and implemented with the changes suggested by the pilot studies herein described, this study will contribute to research on instructional technology effectiveness in several ways.

It will offer a unique comparative situation, with coincident topic presentation across media (multimedia, textbook, in-class instruction). Therefore, it will enable the researcher to control for content-differences biases found in earlier studies. The research design overcomes several limitations of these earlier studies (controlling for time, instructor, and content-differences), and presents a framework that addresses previous concerns.

This research will contribute to the advancement of the debate on effectiveness of instructional technologies by looking at one specific medium, and its comparative impact. In fact, it responds to calls for further research in areas that have key instructional implications for education and training.

By replicating this research with undergraduate and graduate students, with higher and lower complexity topics, and contrasting direction and magnitude (effect size), this research offers further validation procedures. The replication also differentiates learning and satisfaction by groups (undergraduate and graduate), and topic complexity. Statistically significant differences among the age groups, for example, allow the measurement of media effectiveness on different learner populations. Learning goals may not be achieved because the learner's developmental stage (Piaget & Inhelder, 1969) has not reached the level of sophistication that benefits from the medium instructional approach. Or, they may not be achieved because the complexity of the topic requires different instructional representations to foster understanding first, then, retention and application. This study helps investigate these relationships by including these dimensions in the research design.

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